DOCUMENT RESUME

ED 078 677 EM 011 224

AUTHOR	Neal, J. P.; Meller, D. V.
TITLE	Computer-Guided Experimentation-A New System for Laboratory Instruction.
INSTITUTION	Illinois Univ., Urbana. Computer-Based Education Lab.
REPORT NO	CERL-R-X-30
PUB DATE	Jul 71
NOTE	25p.; Paper presented at Symposium on Applications of Computers to Electrical Engineering Education (Lafayette, Indiana, April 27, 1971)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	College Students; *Computer Assisted Instruction; *Computer Based Laboratories; Computers; *Engineering Education; Experiments; Higher Education; Instructional Aids; *Laboratory Equipment; *Laboratory Procedures; Program Descriptions; Program Evaluation; Time Sharing
IDENTIFIERS	*PLATO Computer Assisted Instructional System; University of Illinois

ABSTRACT

This paper reports the development, operation, and initial performance evaluations of an electrical engineering laboratory station equipped for computer-guided experimentation (CGE). A practical evaluation of the actual instructional value of two programed lessons utilizing this new system for laboratory instruction and experimentation is also included. The prototype laboratory station fitted for CGE automatically feeds back information reporting a student's laboratory activities (namely, his settings of instrument dials and the interconnections he makes between the terminals of his experimentation equipment) to a time-shared computer assisted instructional (CAI) system, so that the student is guided automatically through a lesson in any manner preprogramed by an instructor. The expansion of these facilities is contemplated when additional CAI stations become available as a result of future expansions of the PLATO CAI system and the University of Illinois. (Author/PB)

ED 078677

CERL REPORT X-30 JULY, 1971

COMPUTER-GUIDED EXPERIMENTATION - A NEW SYSTEM FOR LABORATORY INSTRUCTION

J. P. NEAL
D.V. MELLER

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY

Computer-based Education Research Laboratory

University of Illinois Urbana Illinois

FILMED FROM BEST AVAILABLE COPY

EM 011 034

ED 078677

COMPUTER-GUIDED EXPERIMENTATION - A NEW SYSTEM FOR LABORATORY INSTRUCTION

J. P. Neal, senior member, IEEE, and D. V. Meller

Abstract - This paper reports the development, operation, and initial performance evaluations of an EE laboratory station equipped for Computer-Guided Experimentation. A practical evaluation of the actual instructional value of two programmed lessons utilizing this new system for laboratory instruction and experimentation is also included in this paper.

The prototype laboratory station equipped for Computer-Guided Experimentation will automatically feedback information reporting a student's laboratory activities (namely, his settings of instrument dials and the interconnections he makes between the terminals of his experimentation equipment) to a time-shared computer-aided instructional system, so that the student can be guided automatically through a lesson in any manner preprogrammed by an instructor.

It is contemplated that these facilities will be expanded to a number of laboratory stations when more CAI stations become available as a result of future expansions in the PLATO computer-based educational facilities at Urbana.

This paper was presented on April 27, 1971, at the Purdue 1971 Symposium on Applications of Computers to Electrical Engineering Education, Purdue University, Lafayette, Indiana.

The authors are teacher and undergraduate student, respectively, in the Electrical Engineering Department, College of Engineering, University of Illinois, Urbana, Illinois 61801.

INTRODUCTION

Terminology

Programmed Instruction (PI)[1] is a general term encompassing various organized presentations of instructional material that apply modern learning concepts and provide a procedure by which any individual student can proceed independently and efficiently at his own pace toward the achievement of preselected learning objectives. Programmed texts [2] are one of the methods most widely used at this time for presenting programmed instruction.

Computer-Aided Instruction (CAI) systems present programmed instruction with greater flexibility and sophistication than can be achieved in a printed text. A student work-station or terminal of the PLATO computer-aided instructional system [3] at the University of Illinois in Urbana consists of a television screen and a keyset linked electrically to a time-shared high-speed computer. The presentation of programmed instruction to a student at an experimentation station in the laboratory requires a closer interaction between a CAI system and the experimentation equipment than is achieved by simply installing a student's CAI terminal at the student's experimentation station in the laboratory. This assertion is justified by comparing the CAI terminal to a blindfolded instructor.

Any experienced instructor of an introductory laboratory course will appreciate the frustration he would feel if he was blindfolded while trying to help an inexperienced student locate an error in his equipment arrangement or measurement techniques. He (the blindfolded instructor) would have to depend on a dialogue with the student while searching for the error. Such

frustration would arise when the student persisted in misreading dial positions, misunderstanding circuit connections, or otherwise misinterpreting some other characteristic of the physical system. A CAI system would be similarly frustrated in guiding a student through a programmed instructional sequence, if the CAI system had to depend on a dialogue conducted with the student at a CAI terminal for the purpose of gaining accurate information describing the physical setup baffling the student.

Reliable automatic guidance can be provided in the laboratory at a student's experimentation station by a CAI system if an electrical logic system or interface between the CAI terminal and the student's experimentation equipment can report reliable information about the student's actual experimental setup whenever the CAI system is programmed to request it. A laboratory station at which the student's experimentation equipment and an adjacent CAI terminal is electrically interfaced in this manner is called a Computer-Guided Experimentation station [4]. The word guided is used to emphasize that true automatic guidance principles apply since the program is controlled by information fedback automatically and independently of the dialogue with the student.

The term experimentation is used here with a broad meaning, referring to any exploration of physical reality at any level of complexity. As a student acquires manual and intellectual skills, he becomes capable of accomplishing higher levels of experimentation [5] ranging initially from familiarization with instruments to the performance of sophisticated experiments of his own creation.

In a similar broad sense, the term lesson is used to refer to any programmed experiment. Various ambiguous terms such as, exercise, test, demonstration, etc. will not be used to distinguish explorations of various levels of complexity. Hence, a lesson may cover a simple exploration of the external features of an instrument, or it may cover a sophisticated experiment.

Background

Printed programmed instructions for laboratory exercises to permit students to familiarize themselves with laboratory instruments or demonstrate for themselves basic phenomena being studied in theory courses have been used for a number of years [5]. Rack-mounted EE laboratory equipment of the type illustrated in Figure 1 was originally acquired here at the University of Illinois at Urbana for use with such programmed instruction.

During the academic year 1968-69, programmed exercises [6] were used as the scheduled experiments in our introductory electrical engineering laboratory course. Generally, the student reaction to using these exercises as scheduled experiments was unfavorable. In order to direct the students to perform a specific task or demonstrate a specific phenomena, each exercise stated every circuit connection, dial setting, reading, and calculation the student should make. Consequently, the completion of an exercise was not a thought-provoking task and, in many cases, the exercises aroused little interest or learning.

During 1968, it became apparent that more interest and learning could be stimulated if students were given specific objectives, broader directions,

and greater freedom of action. However, introductory experiments presented in this manner would require closer instructor guidance to prevent misinterpretation or hopeless confusion. Programmed texts requiring conscious choices of actions and alternate routes could be prepared, but their use in a laboratory becomes cumbersome. Furthermore, if a student unintentionally adjusted or connected equipment incorrectly, the programmed instructions could also lead to misinterpretations or hopeless confusion and instructor assistance would still be necessary before he could proceed with the laboratory lesson. As a consequence of these experiences, no effort has been made at Urbana to develop printed programmed texts for the introductory EE laboratory course taken by about 250 sophomore EE students per year. Nevertheless, we continue to use a printed programmed exercise covering the operation of an oscilloscope for the initial experiment in that course.

CURRENT RESEARCH OBJECTIVES

Thoughtful consideration of the above experiences led to the initiation of two teaching research projects in 1968. The first project had the objective of improving the lecture-discussion periods associated with the introductory laboratory course by involving all laboratory instructors in the lecture-discussions and stimulating the interest and participation of students during these presentations. The results of this project have been reported elsewhere [7, 8]. The second project covers Computer-Guided Experimentation. Progress on this project is reported in this paper.

Research on Computer-Guided Experimentation has the objective of developing and testing a method for automatically guiding a student's laboratory

experimentation by means of computer-aided instruction automatically modified according to electrically fedback reports of the students' actual laboratory activities, such as his adjustments of dials and switches, and the connections he makes between the terminals of electronic laboratory equipment. Time-shared computer-aided instruction, like that available through PLATO [3] at Urbana, seemed worthwhile because a library of introductory lessons or experiments of various levels of difficulty could provide a wide range of choice to beginning students and give them the freedom to experimentally explore equipment and systems of immediate interest, rather than forcing all students to follow an identical schedule that could bore some of them and swamp others. Automatic direct sensing of each student's actual terminal interconnections and instrument dial adjustments seemed necessary, rather than relying on student's reports of such activities, so that appropriate programmed guidance could be reliably selected and activated whenever a student became too frustrated from progress towards his selected experimental objective.

Each lesson or experiment is developed, programmed, stored on the computer, and tested for its effectiveness. Automatic guidance is selected, structured, and activated during any lesson at any time and in any manner provided in the instructor's programming of that lesson.

The future possibilities of a reliable system of Computer-Guided Experimentation are wider than the impression conveyed by the above discussion. It seems reasonable to expect that a computer program can be prepared that will permit a student to devise and plan an original experiment,

receive a variety of automatically programmed guidances, such as, suggestions for various avenues of exploration, warnings of connections between terminals or dial adjustments that do not conform to his stated plan, or warnings of dangerous mishandling of the laboratory equipment.

PRESENT COMPUTER-GUIDED EXPERIMENTATION EQUIPMENT

One prototype Computer-Guided Experimentation (CGE) station for student use was placed in operation in the Computer-based Education Research Laboratory (CERL) at Urbana in October 1970. This CGE station consists of electronic experimentation equipment and a student terminal of the PLATO time-shared computer-aided instructional system mounted side by side on a large laboratory table, approximately as shown in Figure 2. The rack-mounted electronic equipment consists of a dual-trace wide-band oscilloscope, a square, triangle, ramp, or sine wave voltage generator, a more powerful sine wave voltage generator, a constant current-voltage supply, and a vacuum tube voltmeter. A general-purpose circuit board and various alternate printed circuit boards are equipped with automatic terminal sensing connections cabled to connectors that can be plugged-in at the front of the equipment panel. The present PLATO station equipment consists of a portable television set and a cable-connected table-top keyset.

The rack-mounted instruments are standard commercial items that we have modified internally to provide signal outputs reporting dial positions and terminal interconnections. We originally contemplated installing binary wafers on each dial or knob shaft so that a binary number output would signal the position of that shaft. The multiplicity of wires required to report each binary number (five wires for a five digit binary number) discouraged this idea. We have installed a potentiometer on each manually-adjustable shaft. With this method, a voltage to ground transmitted by a single wire

provides a signal reporting the position of the associated shaft. Whenever directed to do so by a lesson program, a programmed electrical logic system sequentially selects a wire from each shaft potentiometer and reports to PLATO the associated dial or knob position by means of the binary number output of a single analog-digital converter. This system for automatically reporting the positions of the 22 adjustable dials and knobs of the electronic experimentation equipment is called the "Dial Checker."

Each electrical terminal on the electronic equipment and on whatever circuit board is in use is also connected through a sensing wire to the electrical logic system. Whenever directed to do so by a lesson program, the logic system serving as the electrical interface between the electronic station equipment and PLATO automatically disconnects any electrical power supplied to the experimentation circuit and then senses and reports to PLATO every interconnection between the electrical terminals. This system for automatically reporting all the interconnections between the 30 accessible electrical terminals on the experimentation equipment is called the "Connection Checker."

As indicated above, the station logic system operates under the control of any programmed lesson as shown schematically in Figure 3 and is available at any time during a lesson. The students' keyset is deactivated while any dial or terminal check is in progress, and the outputs of the logic system are reported to the time-shared computer-aided instructional system like normal binary number inputs of the student keyset. The data output rates of the present logic system are: for the Dial Checker - 22 dial positions

(22 characters) in less than 2 seconds; for the Connection Checker - 30 terminal interconnections (150 characters) in less than 8 seconds.

The hardware and software for the Dial and Connection Checkers for the prototype CGE station were designed and constructed by 12 graduate and undergraduate EE students working on a part-time basis. The operation of this system is not infallible, so two students are continuing the effort to improve the construction and operation of this system. They are gaining valuable experience with analog and digital systems during this work, and are progressing satisfactorily.

The operation of the Checkers has been sufficiently reliable to enable us to test a few lessons. Prior to this spring, ten undergraduate EE students have participated in this educational research by studying the design and preparation of suitable lessons. During this Spring Semester, 7 students are engaged in designing introductory experiments, programming a number of introductory Computer-Guided Experimentation lessons, and evaluating their educational worth. A few beginning undergraduate EE students have worked through our present lessons at the prototype CGE station.

COMPUTER-GUIDED EXPERIMENTATION LESSONS

The Development of CGE Lesson Topics

Those of us involved with instruction in laboratory courses would like to give the student freedom in the laboratory. What this seems to mean is that we are willing to permit a student to work on his own if he can use the instruments and other laboratory equipment safely and properly, devise meaningful experiments, and report his laboratory work accurately and clearly. If a student cannot perform those tasks when he begins an introductory EE laboratory course, he certainly should be able to perform them adequately when he completes the course.

How does someone learn to do these things? How does he acquire the necessary manual and intellectual abilities? Our experience indicates that persons familiar with using electronic instruments can learn to use a strange complex electronic instrument more readily than a novice can learn to use a strange simple electronic instrument. Why is this? We believe the task is easier for the experienced person because he has learned manual and intellectual skills and concepts that are transferable and can be applied to the new instrument. For example, a "Range" knob may select the multiplier which must be applied to scale indications, or "Internal" versus "External" may mean "self-driven" versus "externally driven." In one way or another, a novice must spend some time and effort to learn the use of instruments. We believe that a novice will learn the use of an instrument most readily by being guided to learn explicitly the necessary concepts, and we have proceeded on this premise.

We reviewed and redefined the purpose of the introductory electrical engineering laboratory experiments for the purpose of distinguishing suitable lesson goals and ordering the lesson goals within each type of equipment area according to their levels of relative complexity. For example, the sequence of lesson goals pertaining specifically to the series of lessons devoted to experimental studies of the Function Generator were ordered as follows:

Level 1 - The operation of the Function Generator.

Level 2 - The determination of the limits of the parameters of the various outputs available from the Function Generator.

Level 3 - The determinations of equivalent network representations for the Function Generator as viewed from its output terminals.

Level 4 - Function Generator experiments of greater complexity or sophistication than those developed for the preceding levels.

Level 5 - Lesson programs that will permit a knowledgeable student to report to the CAI system a definite plan for an original experiment employing the Function Generator and thereafter be given guidance automatically as he performs that experiment.

The Construction of CGE Lessons

Since 1968, members of our Computer-Guided Experimentation group have been devising, programming, and testing lessons in experimentation. This experience and our other studies of educational psychology, computer-aided instruction, and instruction in laboratory courses, plus considerable help from the literature [2, 9], have led us to define and order the following list

of steps as a guide for constructing a CGE lesson:

1. Identify the subject matter or topic of the lesson.
2. Determine and state the goal of the lesson concisely in behavioral form.
3. Determine the objectives of the lesson and state them in behavioral form. Each objective is one of the mental or physical abilities that a student must have or acquire to accomplish the lesson goal. This list of behavior objectives is not intended to be exhaustive, nor is it presented to the student as an exhaustive list of the things he will be able to do when he successfully completes the lesson. The list simply includes the least things the student must be able to do to achieve the goal of the lesson.
4. Perform a task analysis for each objective. A task analysis is a flow chart relating whatever objective that is located at the apex to lower or subordinate abilities that a student must have or acquire before he can achieve the apex. Each task analysis should be extended downward to whatever minimum level of abilities it is reasonable to assume will be within the capabilities of all students.
5. Construct a test to measure the attainment of the objectives. If a student can achieve each of the objectives, he should be competent to achieve the goal of the lesson.
6. Prepare the instructional material for each display frame as necessary to guide a student to acquire higher and higher levels of abilities until he achieves each objective.
7. Within every frame or two, as material frames are prepared, construct and incorporate a criterion test to verify that each new ability is

properly acquired.

8. Design the feedback for both right and wrong answers to the criterion tests and the objective tests and determine the proper frames to which the student should be guided.
9. Test and improve the lesson and evaluate its instructional worth.

The steps listed above tend to shape the lesson into a sequence with simple branches, and it is an easy and effective way to start the development of any lesson. It is well to remember that any lesson is not a competent educational tool until practically all of the students for whom it was designed can complete the lesson satisfactorily and are inspired to continue to higher levels of learning.

A Typical CGE Lesson

The Level-1 lesson numbered EEX1Ø on the Exact Model 250 Function Generator is used in this section for the purpose of exemplifying the above-listed steps for constructing a CGE lesson. The item numbers below coincide with applicable step numbers in the above-listed lesson construction guide. The Function Generator is mounted below the oscilloscope in the prototype CGE station as illustrated in Figures 1 and 2.

1. Topic of Lesson: The operation of an Exact Model 250 Function Generator, Lesson EEX1Ø.
2. Lesson Goal: After satisfactorily completing this lesson, a student should be able to properly connect the Function Generator into an experimental system as a 2-terminal source and drive the system with a voltage having any specified waveshape and parameters within the rated capacity of the Function Generator.

3. Lesson Objectives: "Within the inherent limitations of the Exact Model 250 Function Generator, you must be able to:

   a) Turn the generator off and on.

   b) Set the triggering system to the desired trigger mode.

   c) Adjust the timing dials to the desired frequency.

   d) Set the generator output to supply the desired wave shape.

   e) Adjust the maximum and minimum voltages of the output to the desired values."

4. See Figure 4 for a typical Task Analysis, namely, the Task Analysis for Objective (a) of this lesson (EEX1Ø).

5. One of three questions used as the test for the attainment of the objectives in this lesson is:

   "Set the dials on the generator to the positions where the output will be:

   (1) Continuously on.

   (2) 2ØØ Hz.

   (3) Adjustable, triangle wave.

   then press - NEXT -"

   The student's answers (actual dial adjustments) are then graded automatically by the Dial Checker and he is guided to proceed in the lesson or learn something he missed.

6. A display frame that was prepared for instruction under objective (c) appears as follows:

"TIMING"

The present settings of the MULTIPLIER and CYCLES/SEC dials define an output frequency of about 6.2×10^2 Hz.

Using "m" MULTIPLIER setting and "s" CYCLES/SEC setting, complete the formula whereby you can predict the output frequency, given any m and s.

f = _____ "

7. The last half of the example in Step 6 above, is a criterion test. It tests the student's understanding of the concept of prescribing a numerical value by fixing the significant digits and a multiplier. The computer was programmed to respond to the student's answers as follows:

For a right answer: "That's it!"

For wrong answer: "I was looking for m x s, i.e., the product of the two settings."

8. The feedback instructions covering the action to be taken on the alternative answers to the criterion test quoted above in Step 7, guide the CAI system to wait until the student inserts the correct answer in the space provided in the frames displayed in Step 6 and then displays the next frame.

9. This lesson on the Function Generator has been tested and revised many times. A printout of this entire lesson is too lengthy to be included in this paper.

Use of the "Dial Checker" in the Typical CGE Lesson

Wherever we needed to know the actual positions of the dials of the Function Generator during a lesson, we simply inserted a computer subroutine that calls the Dial Checker. Throughout the typical lesson discussed above, the Dial Checker was used in three ways:

(1) To verify that the student set the dials to the positions required for the demonstration of a specific phenomenon.

(2) To test whether the student could set the dials properly to produce a specified output. This use is employed in the automatic grading mentioned above in Step 5 where a question of an attainment test is exemplified.

(3) To present information calculated on the basis of the actual dial positions as exemplified by the statement "6.2×10^2 Hz." in the frame illustrated above in Step 6.

After a student is directed to set certain dial positions, the Dial Checker automatically senses the new dial positions and feeds this information to the CAI system. The CAI system compares this "actual" data to a preprogrammed set of "correct" data and is usually programmed to display to the student the names of those dials which are set incorrectly. If no dials are incorrectly set, then an appropriate complimentary message may be displayed. When the given output description and the error data are displayed simultaneously to a student, he can easily correct the errors before he proceeds.

Current Results of CGE Lesson Research

The Level-1 CGE lesson on the Function Generator that was discussed in the preceding section consisted of 17 display frames, including 3 frames devoted to a final test. The lesson covered the Trigger, Timing, and Output divisions of the Function Generator. Data records were collected for 8 students who completed the test individually, at different times when the prototype CGE station was operative. Their average completion time for the lesson was 27 minutes (extremes were: 19 and 35 minutes). There were 9 student responses required in the instructional portion of the lesson and 16 dial settings required in the final test in the lesson. Of the 8 x 9 = 72 required student responses, there were 18 wrong responses. 12 of these wrong responses were replies to two poorly stated questions. Of the 8 x 16 = 128 required dial settings, there were 11 wrong dial settings made by the students.

A similar Level-1 CGE lesson on the HP 200 AB Audio Oscillator was completed by 10 students in an average time of 13 minutes (extremes: 10 and 19 minutes). For these students there were 10 out of 50 wrong student responses during the lesson and 8 out of 80 wrong dial settings during the final test.

All errors in lesson responses or dial settings in the final tests were corrected by the students before they completed these instructional units. The percentage of errors for these two CGE lessons may be tabulated as follows:

	Function Generator	Audio Oscillator
Lesson Errors	25%	20%
Final Test Errors	9%	10%

It will be interesting to learn the extent to which student performance during the above lessons is improved when the one or two poorly stated frames in each of the above lessons are modified.

CONCLUSIONS

We find certain circumstances very interesting. While taking the CGE lessons, the students unquestioningly accepted the computer's report of dials that were set incorrectly. When the error message was displayed, the students immediately began to analyze their setup and, without exception, corrected their errors on the first attempt. All 18 of the students, who completed a lesson, properly adjusted their particular instrument when they were given a verbal description of a required output. Hopefully, these skills would be reinforced and retained by having the students use the instruments in subsequent CGE lessons.

The student's attitudes and reactions while taking the CGE lessons seemed very favorable. From both lessons, the most frequent student comments were: "Some of the wording [in the frames] was hard to understand"; and "PLATO [referring to the Computer-Guided Experimentation station] is helpful and the course [referring to our present introductory EE laboratory course] is a must for EE students. It will be great if the two can be combined."

Our experience with the use of the Dial Checker in providing automatic guidance in the CGE lessons has been so encouraging that we are finding new ways to use this kind of information to enhance CGE lessons. We have barely begun to understand how to use the wealth of information available from the Connection Checker.

Within the near future, we plan to complete the programming of a CGE "lesson" that will allow the student to establish the actual lesson presentation, rather than simply presenting all instruction in the essentially sequential form used in present tutorial or inquiry teaching strategies. This should eliminate the lock-step which is inherent in tutorial sequencies and create an even more effective learning program.

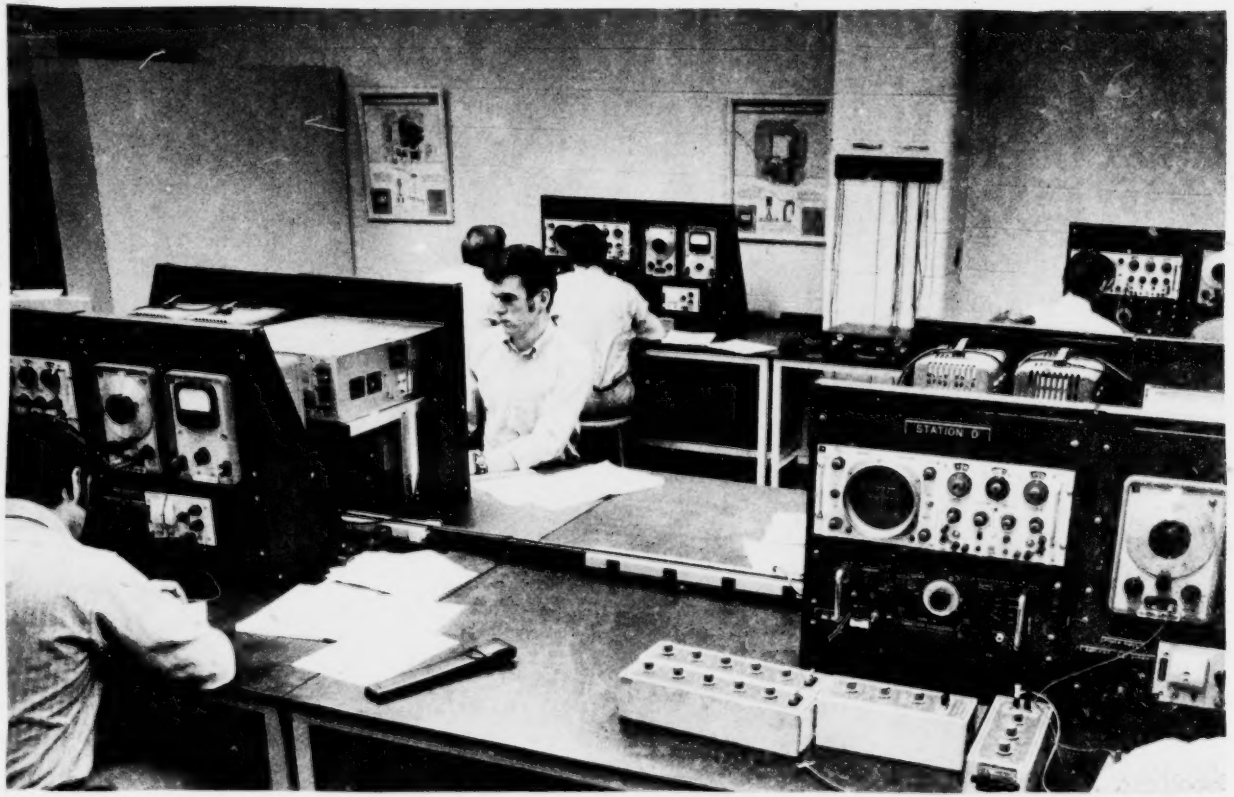
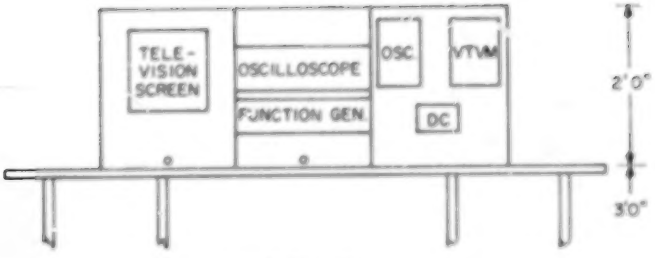


Fig. 1. A View of the Introductory Electrical Engineering Laboratory.



FRONT VIEW

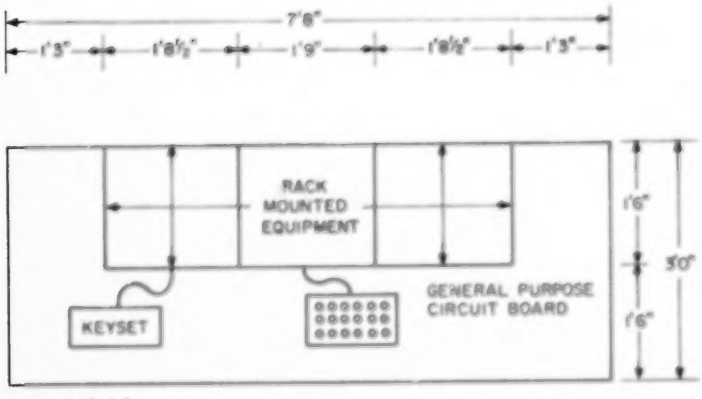


TABLE-TOP VIEW

Fig. 2. The Prototype Computer-Guided Experimentation Station.

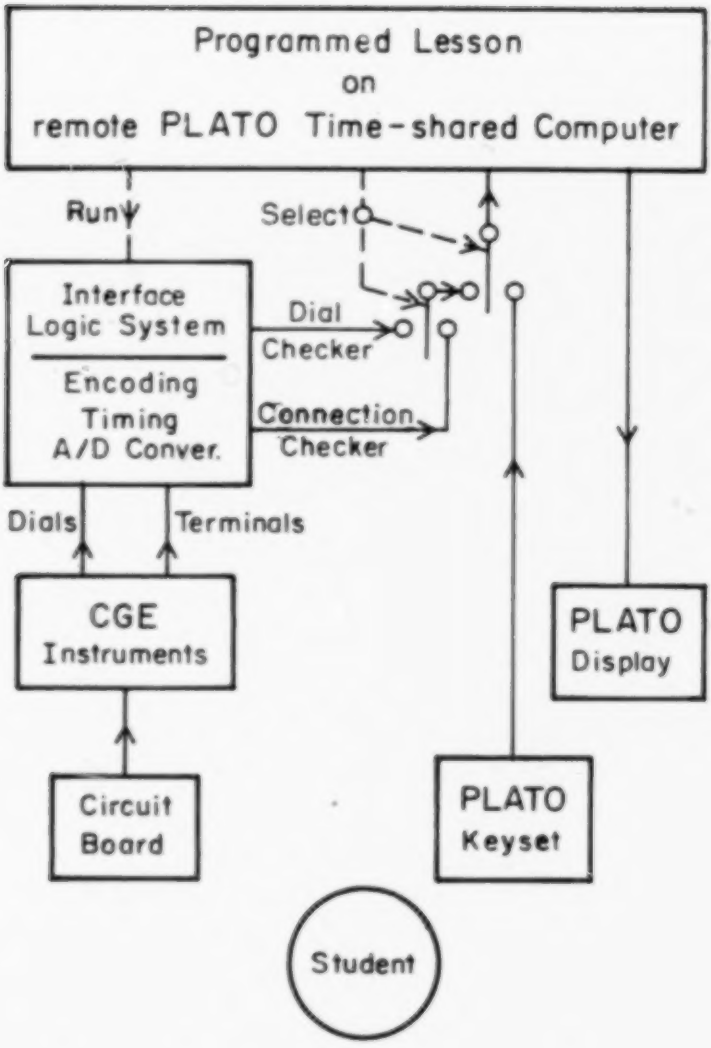


Fig. 3. CGE Station Schematic Diagram.

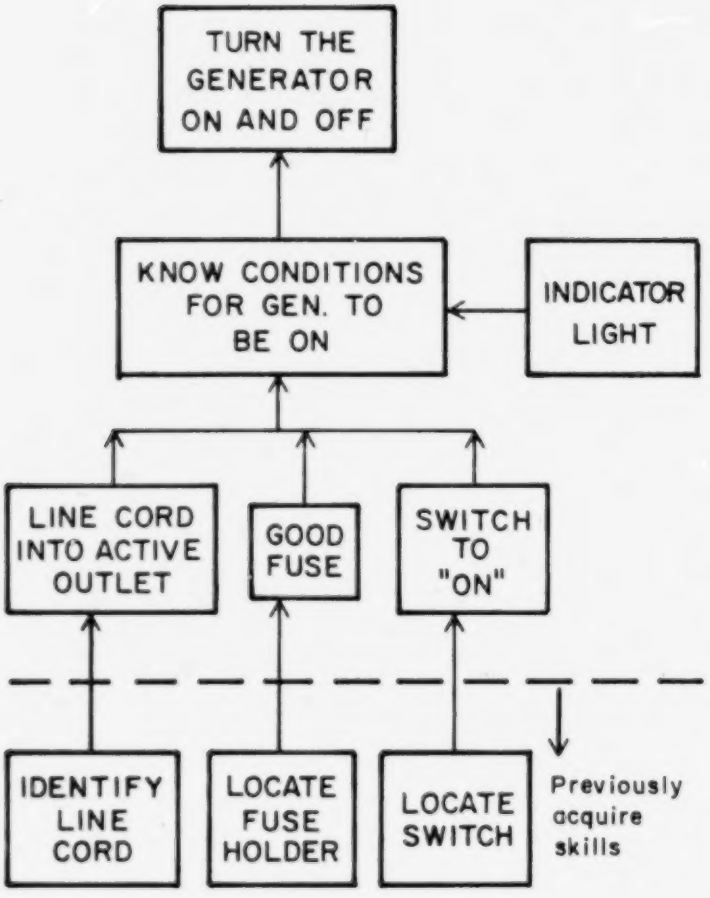


Fig. 4. Task Analysis for Objective (a) of Lesson EEX1Ø.

REFERENCES

[1] R. K. Moore, "Programmed Instruction - The Engineering of Education", IEEE - Education, E-6, Dec. 1963, pp. 60-64.

[2] N. Balabanian, "The Educational Engineering Called Programmed Instruction", IEEE - Education, E-9, June 1966, pp. 49-57.

[3] D. Alpert and D. L. Bitzer, "Advances in Computer-based Education", Science, 167, 20 Mar 70, pp. 1582-1590.

[4] J. P. Neal, "The Self Teaching Electrical Engineering Laboratory (STEEL) Program for Computer-Guided Experimentation", Computer-Oriented Electrical Engineering Experiments 1969-70, Commission on Education, The National Academy of Engineering, p. 11.

[5] R. M. Gagne, "Some New Views of Learning and Instruction", IEEE - Education, E-14, Feb. 1971, pp. 26-31.

[6] J. O. Kopplin, E. W. Ernst, and E. C. Jones Jr., "Programmed Experimental Teaching Exercises", IEEE - Education, E-6, Dec. 1963, pp. 71-75.

[7] J. P. Neal, "Nurturing Creativity in a Measurements Course, "Proceedings of the 24th Annual ISA Conference, Houston, Texas, 28 Oct 69, paper number 603.

[8] J. P. Neal, "Cooperative Instruction in a Multisection Laboratory Course", IEEE - Education, E-13, July 1970, pp. 9-10.

[9] R. F. Mager, "Preparing Instructional Objectives", Fearon Publishers, Palo Alto, California, 1962.